Spatial Analysis of Natural and Anthropogenic Factors Influencing Chimpanzee Repartition in Sebitoli (Kibale National Park, Uganda)

Sarah Bortolamiol[1,2,3,6,] **Sabrina Krief**[3,6,] **Frederic Jiguet**[4,] **Milena Palibrk**[5,] **Protase Rwaburindore**[7,] **John Kasenene**[7,] **Andrew Seguya**[8,] **Marianne Cohen**[1,2,5, 6.]

[1] Université Paris Diderot – Paris 7, 5 rue Thomas-Mann - 75013 Paris.
[2] UMR LADYSS - 200 avenue de la République - 92001 Nanterre cedex.
[3] UMR 7206 - Eco-anthropologie et ethnobiologie, Muséum national d'histoire naturelle - 43 rue Buffon - 75231 Paris Cedex 5.
[4] UMR 7204 - MNHN-CNRS-UPMC 'Centre des Sciences de la Conservation' - 55 Rue Buffon, CP 51 - 75005 Paris.
[5] PPF Pôle Image – Université Paris Diderot – Paris 7, Case 7001 - 75205 Paris cedex 13.
[6] Projet pour la Conservation des Grands Singes (PCGS) - 3 rue Titien - 75013 Paris.
[7] Department of Botany Herbarium, Makerere University - P.O. Box 7062 - Kampala, Uganda.
8 Uganda Wildlife Authority - P.O.Box 3530 - Kampala, Uganda.

Abstract. Using a combination of geographical data, spatial analysis is a precious tool in environmental sciences. Many process are underlying landscape, they are interacting together and having different impacts. We analyzed 4 years of data collected in a wild chimpanzee community using a multidisciplinary method in order to determine natural and human factors that influence chimpanzee repartition. It seem that chimpanzee density is high (4.4 individuals/km^2) even if their home range is circumcised by anthropogenic elements. Chimpanzees are not avoiding forest edges in contact with human population and they are crossing the road passing through their home range.

Keywords: Biogeography, Chimpanzee, Model, GIS.

1. Introduction

Worldwide conservation efforts are trying to cope increasing anthropogenic pressure with disturbance of natural areas due to human activities. Great Apes are facing recent decline in suitable environmental conditions (Junker et al. 2012). Among them, our closest relative, the chimpanzee (*Pan troglodytes*) is threatened (classified on IUCN red list as endangered, IUCN website), because of past and present forest exploitation, poaching activities and species-specific ecological requirements.

Our study aims to improve understanding of chimpanzees living in a forest area under human pressure. Analyzing landscape, species spatial distribution (vegetal and animal) and factors influencing their repartition could give some keys for a better management of nature conservation in anthropogenic environment.

The interactions between chimpanzees, landscapes and human societies are closely related to spatial pattern and processes and for this reason, spatial analysis is useful to understand and even model them.

First of all, chimpanzees (*Pan troglodytes*) prefer certain habitats and they are supposed to be more abundant in places where environmental conditions are optimal (Turner et al. 2003, Kerr & Ostrovsky 2003) and food resources abundant (Potts 2009, Hockings et al. 2009).

Second, chimpanzees have a typical territorial behavior (Caldecott & Miles 2009, Goodall 1986) related to their fission-fusion social organization.

Third, interactions between human societies and chimpanzees are depending from the proximity between them (Naughton-Treves et al. 1998, Hartter et al. 2010) and occur within the edge between the protected forest and the agricultural landscape that surrounds it.

The aim of spatial analysis in ecology is to identify patterns that help understanding ecological processes (Fortin et al. 2006). Geographers use points, lines, areas and surfaces to describe spatial organization (Fotheringham et al. 2000), underlying continuities and discontinuities in space (Alexandre et al. 2008). In this study, we combined several techniques and methods to tackle our objective.

The following article will start by a description of the study site followed by the method section, and then the results we obtained by the set of methods.

2. Materials and Methods

2.1. Materials

2.1.1. Study Site

Kibale National Park (795 km^2), located in southwestern Uganda (fig.1), is well known for its high diversity of plants and mammals. The habitat is a mosaic of mature forest (58%), colonizing forest used for agriculture in the past (19%), grassland (15%), woodland (6%), lakes and wetlands (2%) (Struhsaker 1997, Chapman & Lamber 2000, Chapman et al. 1997). Since1993, the forest has been classified as a National Park and is under management of Uganda Wildlife Authority (UWA).

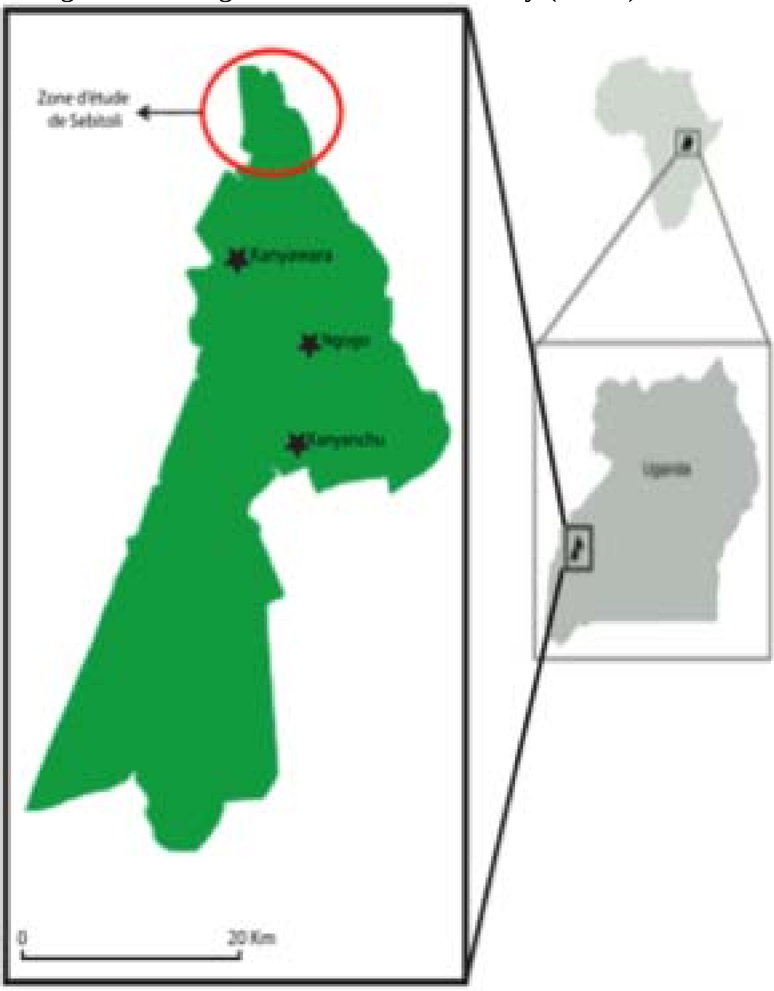

Figure 1. Location of Kibale National Park and Sebitoli study area.

A thousand Eastern chimpanzees - *Pan troglodytes schweinfurthii* – are organized in several chimpanzee communities, with varied densities

(Kanyawara 1,5 i/km^2, Ngogo: 5.1, Potts 2009). Chimpanzee need up to 10 years to be observed and to get habituated[1] to the presence of humans.

Sebitoli study area, located extreme north of the park (*Figure 1*), includes the protected forest and the agricultural area bordering it. The density of chimpanzees is higher than 2 individuals/km^2 (unpublished data, collected by Sebitoli Chimpanzee Project supervised by S. Krief). Human activities are frequent at the edge of the forest and inside (tarmac road). Many mammals are going outside the forest border to feed in neighboring gardens (Naughton-Treves 1998). Human communities are also entering the forest for illegal activities sometimes (MacKenzie et al. 2011).

We are analyzing 4 years of data collected in this area from February 2009 to January 2013.

2.1.2. Data

2.1.2.1. Imagery

A first step consisted in gathering imagery resources since no data on Sebitoli had ever been compiled. We first used 1964 topographical map of Fort Portal (1/50 000^e, Royal Museum of Central Africa – Tervuren, Belgium) and a set of images captured from Google Earth Pro (23/06/2001 – N=11 – Premium resolution 4800 x 4775 pixels) assembled with Photoshop CS5 to create a mosaic picture of Sebitoli study area.

Landsat image (Landsat 7 - ETM+, 30m resolution, orthorectified, 14/03/2001) was used to create a land-cover map. Also, recent acquirement of Spot image (2,5m, color, orthorectified, 28/11/2008) allowed use to update and digitalize landscape elements. Finally, we also used a Digital Elevation Model (SRTM image – 30m resolution) from which we extracted slopes and elevations.

2.1.2.2. Botanical Information

We surveyed botanical information in 62 50x50m plots located inside the forest, and 17 outside. In the protected area, we placed plots randomly using a stratified method where the number of plots is proportional to superficies of each land-cover class previously defined with Landsat image (*Section 2.2.1*). The 17 plots located outside the forest were sampled according to the type of edge, i.e. the type of landscape in contact according to land-cover classification.

Plot census was conducted with the help of two field assistants and Makerere University Botany Herbarium Department.

From georeferenced datasheets of chimpanzee habituation, we determined the species most consumed by chimpanzees.

---

[1] Habituation, defined in primatology by Johns (1996), is a process in which chimpanzees fleeing reaction decrease with frequency of contacts with humans.

2.1.2.3. Chimpanzee Monitoring

The chimpanzees survey, made by field-assistants, is helped by moving transects (mapped on *Figure 2*) designed to access dense forest more easily. Chimpanzee presence (feces, direct observations, nests, footprints, vocalizations) is located with GPS points; distance of chimpanzee(s) from observers, orientation, number of individuals, if possible their identity, activities and other information related to their behavior (for instance, consumed species) are specified. Anthropogenic signs (fire camp, snares, noise, footprints) are also gathered during the survey and their geographic coordinates are recorded in GPS.

Type of signs	Direct observations	Vocalizations	Feces	Total
Total	1570	1401	481	3452

Table 1. Number of observation types between February 2009 and January 2013.

2.1.2.4. Socio-economical Information

We conducted 28 semi-directive interviews and participative observations in 3 local communities surrounding the forested area (Sebitoli, Kihingami, Kahangi) from October 2012 to January 2013. Our goal was to understand uses and practices of people living around the park, and their relationships with wild animals. We selected the villages according to their location (proximity to the road, orientation toward forest), land-cover characteristics (presence or absence of elephant trench constructed by UWA to avoid wildlife going out of the park, gardens location) and empirical information about communities (poaching activities signs). We try to represent different population categories and distances to the forest in order to have a representative sample of spatial and socio-demographic diversity encountered around Sebitoli study area.

	Villages	**Sebitoli**	**Kihingami**	**Kahangi**	**Total**
Sex	**Women**	2	5	5	12
	Men	6	5	5	16
Ethnic group	**Batooros**	7	10	4	21
	Bakigas	1	0	4	5
	Others	0	0	2	2
Age	**< 20 years old**	1	1	0	2
	20 – 40 years old	5	6	6	17
	40 – 60	0	2	2	4

	years old				
	Total	8	10	10	28

Table 2. Number of interviews per villages.

One UWA ranger is in charge of contact with public and we used their survey of the crop raiding incidents to determine in which village UWA was carrying more frequent interventions and for which animal species (January 2012 to December 2012).

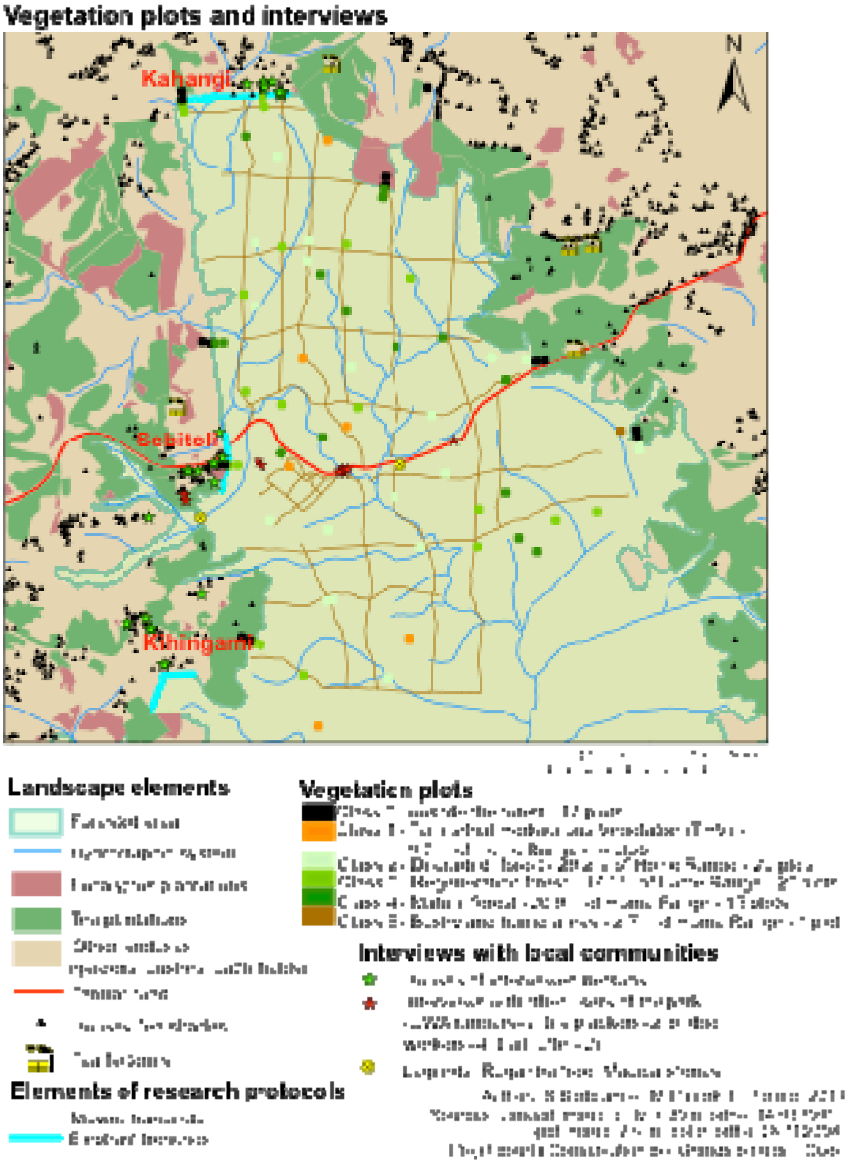

Figure 2. Study area and data collection

2.2. Spatial analysis

2.2.1. Remote Sensing and Vegetation Survey: From Area to Points

We used Envi 4.5 to analyze satellite images of Kibale National Park. We used unsupervised classification followed by PCA on Landsat image to determine 6 different land-cover (from which we placed vegetation plots):

- Class 0: Outside the forest (houses, crops, tea, eucalyptus, road),
- Class 1: Surface of Terrestrial Herbaceous Vegetation (THV),
- Class 2: Surface of degraded forest,
- Class3: Surface of regeneration forest,
- Class 4: Surface of mature forest,
- Class 5: Surface of bushy and humid areas.

2.2.2. GIS Analysis

We used ArcGIS 10.0 (License Arcinfo - ESRI) to integrate maps, images and GPS points, georeferenced in the WGS 84 geodesic system and UTM 36N cartographic projection. ArcTool box and ETGeowizard allowed us to perform spatial analysis treatments.

2.2.2.1. Digitalizing Landscape Elements

We digitalized landscape elements such as eucalyptus plantations, hydrographic system, roads, forest edge, houses and plantations from topographical map of Fort Portal, Google Earth mosaic and Spot image.

2.2.2.2. Representing Chimpanzee Home Range: From Points to Area

We used Polygon Convex Minimum method (PCM, Mohr 1987) available with ETGeowizard, in order to connect GPS points and define the boundaries of Sebitoli chimpanzee home range (Steiniger et al. 2010, Dickson et al. 2005). We disregard external points corresponding to vocalizations and crop-raiding events.

To determine if chimpanzee home range was frequented equally, we calculated Kernel density estimator. We normalized the result by multiplying values of each range by 0,00165519 (=Total number of chimpanzee observed during the study period/density sum) (Di Salvo et al. 2005).

2.2.2.3. From Points to Grid Cell: Modeling Chimpanzee Repartition

With ETGeowizard, we created a grid of 200 x 200 meter quadrats inside the chimpanzee home range. By intersecting it with other GIS layers (DEM, Land-cover classification, chimpanzees GPS points) we extract the environmental characteristics of each cell of the grid. We performed a Principal Component Analysis (PCA) to avoid problems of auto-correlations, and retained the values of the 4 four Principal Components of the PCA (F1, F2, F3, F4).

	Variable names	
Environmental data used for Maxent analysis	Length of transects (m)	Per quadrat (N=795)
	Mean altitude (m)	
	Mean slopes (%)	
	F1: + mature and regeneration forests/-herbaceous vegetation and degraded forest	
	F2: + degraded and regeneration forests/-humid and bushy areas	
	F3: humid and bushy areas	
	F4: herbaceous vegetation and mature forest	
	Closest distance from each plot centroid to the road (m)	
	Closest distance from each plot centroid to the edge (m)	
	Closest distance from each plot centroid to the river (m)	

Table 3. Environmental variables extracted of the grid cell

Maxent program version 3.3.3 has been used to determine the probability of chimpanzees presence across Sebitoli from this set of data (Elith et al. 2011).

A first step in the modeling framework was to validate the model obtained when using all available observation locations with Maxent. So we first bootstrapped Maxent model 50 times, by randomly selecting for each run 75% of the occurrence locality grid cells as training data with the remaining 25% reserved for testing the resulting model. We used recommended default values as in Junker et al. (2012) for the convergence threshold (10^5), maximum number of iterations (500) and regularization value (10^4), and let the program automatically select ‘features’ (environmental variables) following default rules according to the number of presence records (Phillips et al. 2006). Overall model performance was evaluated by means of the ‘Area under the Curve’ (AUC) determined by the Receiver Operating Characteristic Curves (ROC) analysis (Phillips *et al.*, 2006). Random prediction (AUC=0,5) would predict 50% of potential chimpanzee repartition surface using 50% of presence data. Therefore, the more AUC and training data curves turn to 1 (and above 0,75 – Fielding et al. 1997), the more the model is trustful. We finally ran a complete model using 100% of observations, which output is presented here (*Figure 7*).

To compare Kernel estimation and Maxent model, we performed a linear correlation between pixel values of Maxent and Kernel grid cells.

2.2.2.4. Measuring edge effect by a buffer analysis

To characterize land use around Sebitoli chimpanzee home range, we created a 2500 meters buffer zone in which we determined the surface of land-use categories.

From our of interviews with local communities, we are using some quantitative information to represent interactions between local communities and wildlife in ArcGis such as frequency of crop raiding observations as well as the public complaints recorded by the Park ranger.

3. Results

3.1. From Area to Points: Landscape and Food Resources Spatial Patterns

The protected forest, including chimpanzee home range, is mostly composed of regeneration forest (37%), followed by degraded forest (28%), mature forest (21%), Terrestrial Herbaceous Vegetation (9%) and bushy/humid vegetation (6%), depicting a more degraded landscape than in the whole Park (*Section 2.1.1*).

The spatial distribution of these types suggests a strong spatial pattern (*Figure 3*), opposing western and eastern sides, probably due to the previous intensive exploitation of timber, when the forest was not yet under protection.

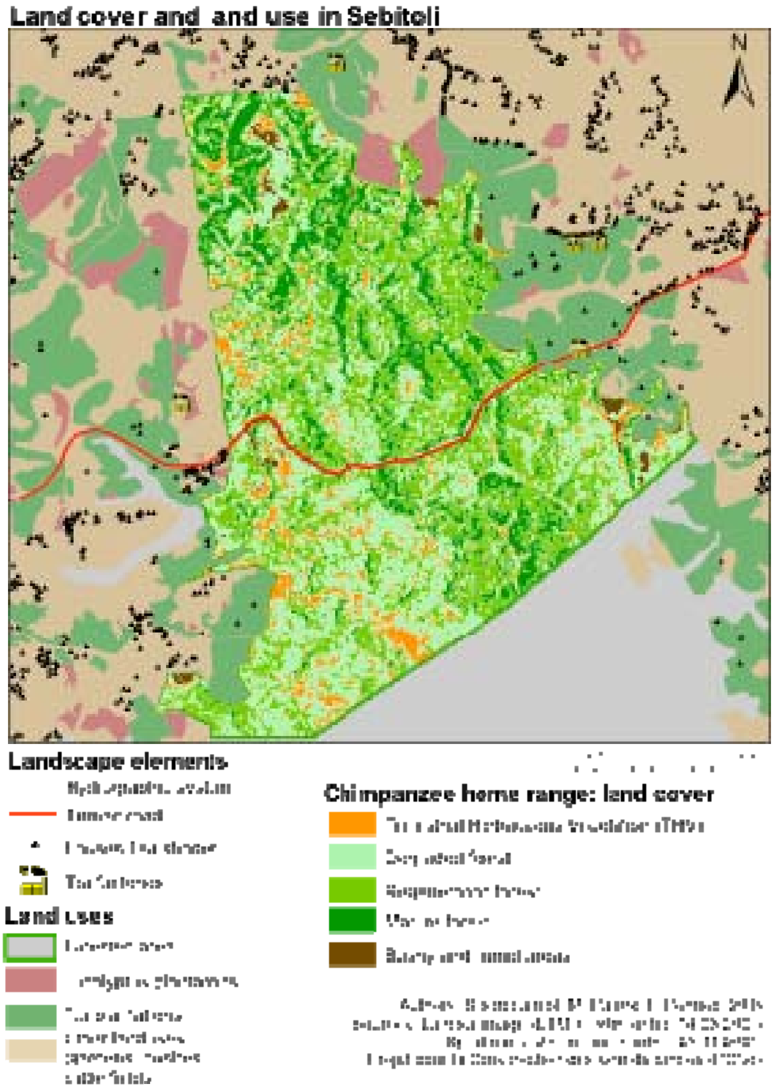

Figure 3. Land-cover and land use in Sebitoli study area.

Tea plantations are more important (21.45 km^2) than eucalyptus plantations (3.37 km^2); only 4 plantations are connected to the park. Houses are observed on the northern and south-western sides of the protected forest. On north-western side, gardens, bushes and cattle-field are close to the forest edge.

3.1.1. Species Availability in Vegetation Plots

In the 62 vegetation plots located in the 5 habitat classes of the forest defined with Landsat, we counted 7163 stems of 362 species (or 205 genus) more or less consumed by Sebitoli chimpanzees (*Tables 4 and 5*)

Tree species recorded in plots	Total	Class 1	Class 2	Class 3	Class 4	Frequence of consumption by chimpanzees
Cordia abyssinica R.Br. ex A.Rich.	51	22	10	8	11	High
Celtis africana Burm.f.	54	4	11	17	22	High
[illegible] sp.	51	1	11	35	4	Low
Chrysophyllum sp.	236	8	67	104	56	Low
[illegible] eminens Hook.f	55	3	12	22	18	Low
Celtis gomphophylla Baker	166	24	43	55	44	Low
Chaetachme aristata Planch.	43	14	12	11	6	Low
Albizia sp.	235	8	67	104	56	Low
Ficus [illegible] Welw. ex Hiern	45	3	12	11	17	Low
Uvariopsis congensis Robyns & Ghesq.	134	3	0	36	95	Low
Neoboutonia macrocalyx Pax	98	2	[illegible]	24	26	Low
Diospyros abyssinica (Hiern) F. White	241	6	103	65	70	Null
Funtumia latifolia Stapf	158	6	70	41	35	Null
Markhamia platycalyx (Baker) Sprague	140	14	47	35	44	Null
[illegible] sp.	128	18	45	37	30	Null
Croton sp.	106	46	40	[illegible]	12	Null
Strombosia scheffleri Engl.	134	3	46	57	17	Null
Bosqueia phoberos Baill.	[illegible]	1	29	11	18	Null
[illegible] sp.	[illegible]	2	36	11	7	Null
[illegible] (Baker) [illegible] Gilbert	58	2	30	15	11	Null
Total sp consumed	1055	87	289	432	344	96884
Total species non-consumed	1132	98	454	428	246	0
Total all species	2187	185	722	740	592	96884

Table 4. Top 20 tree species recorded in plots and their consumption by Sebitoli chimpanzees.

THV species recorded in plots	Class 1	Class 2	Class 3	Class 4	Class 5	Total	Frequence of consumption by chimpanzees
Aframomum sp.	16	63	80	55	0	235	Medium
Piper capense L.f.	5	36	44	25	0	110	Low
Fern sp.	13	282	114	65	23	496	Low
Hypoestes forskaolii (Vahl) R. Br.	9	6	49	141	0	205	Null
Cynodon dactylon (L.) Pers.	0	198	0	0	0	198	Null
Mimulopsis arborescens	14	69	17	83	0	183	Null
Allophylus sp.	35	52	42	53	0	182	Null
Panicum sp.	3	48	72	37	0	160	Null
Unknown tree sp.	17	66	60	11	0	154	Null
Desmodium sp.	21	67	31	19	1	141	Null
Acalypha sp.	0	44	51	34	0	129	Null
Crassocephalum sp.	1	101	3	6	0	111	Null
Cyperus sp.	0	8	0	0	30	98	Null
Psychotria sp.	17	16	40	21	0	94	Null
Commelina sp.	5	23	19	44	0	91	Null
Palisota sp.	1	27	44	19	0	91	Null
Tarenna pavettoides (Harv.) Sim	5	12	16	55	0	89	Null
Aspilia africana (Pers.) C.D.Adams	1	20	15	39	7	82	Null
Dracaena sp.	1	36	29	15	0	82	Null
Brillantaisia cicatricosa Lindau	11	26	12	10	0	59	Null
Total sp consumed	35	403	235	147	23	843	8466
Total species non-consumed	130	793	490	579	98	2090	0
Total all species	155	1196	725	726	121	2933	8466

Table 5. Top 20 THV species recorded in plots and their consumption by Sebitoli chimpanzees.

Forest habitats contain more food resources for chimpanzees than non forest sectors. Feeding trees are abundant in mature and regeneration forest, while herbaceous resources are abundant in degraded forest.

3.2. From Points to Area

3.2.1. Spatial interpolation of chimpanzee observations

Using Polygon Convex Minimum method on the 3452 recorded points, we determined chimpanzee home range was 22.5 km². This home range is located in the northern part of the protected forest, including the tarmac road.

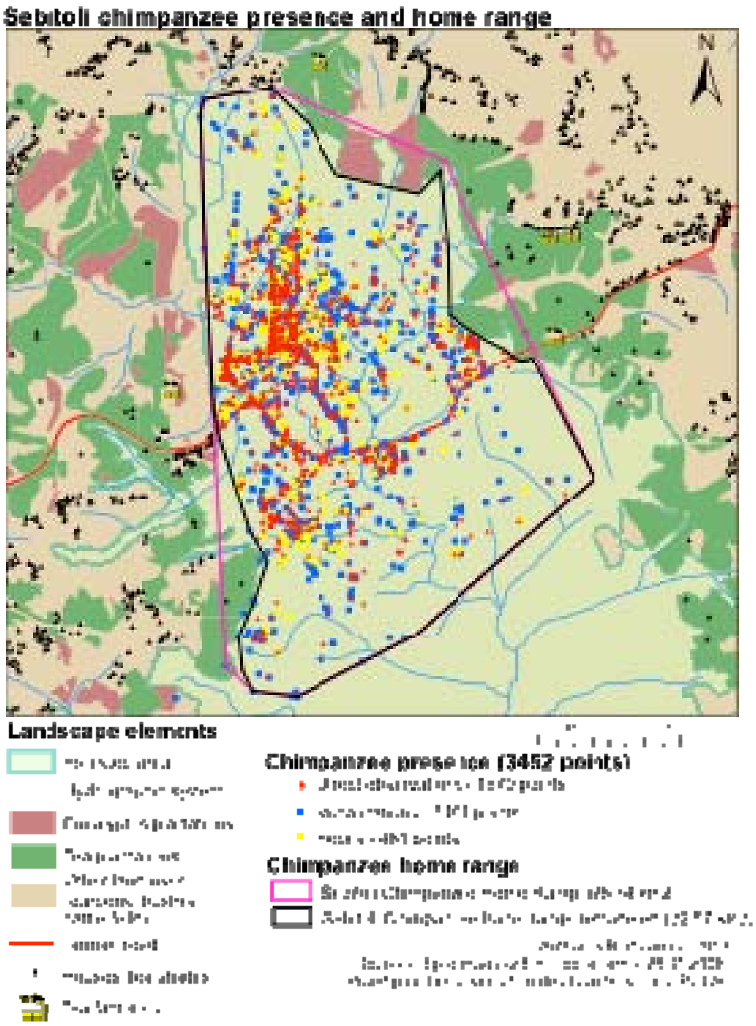

Figure 4. Sebitoli chimpanzee home range

Considering that Sebitoli chimpanzee community counts about 100 individuals at this stage of habituation, we estimate chimpanzee density at 4,4 individuals/km² which is very close to the highest chimpanzee density known in the world (5,1 individual/km² - Potts 2009).

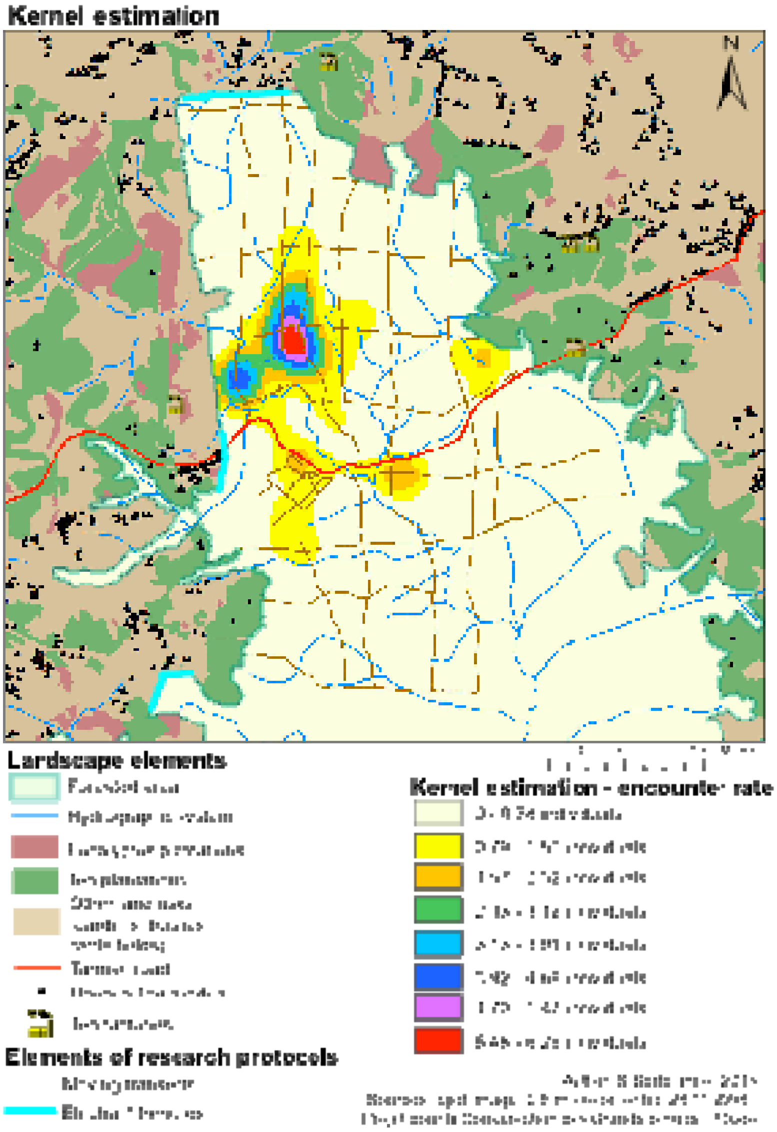

Figure 5. Kernel estimation of most frequented areas of Sebitoli chimpanzee home range.

Kernel density estimator highlights that chimpanzees are concentrate up to 6,26 i/km² in a small patch on the western side of northern compartment of the forest. This area has a heterogeneous land-cover (*Figure 3*), associated with herbaceous and ligneous feeding species (*Section 3.3.2*). This area is close to the edge, which is less human-populated and mainly covered with gardens, bushes and cattle-field.

3.3.2. Modeling Chimpanzee Repartition Within a Grid Cell

Maxent used the set of data gathered in the grid cell and attributes values to each pixel corresponding to chimpanzee presence probability. Most pixels of Maxent model correspond to a medium probability of chimpanzee presence (N=396+273).

The Area Under the Curve (AUC) value of Maxent model (AUC=0,800, maximum = 1) was relevant (above 0, 75, Fielding et al. 1997).

The more contributive variables to Maxent model are: distance to the road (30.1%), the edge (14.6%), the river (13.4%) and mean altitude (13.7%). This confirms that chimpanzee repartition is largely influenced by spatial variables.

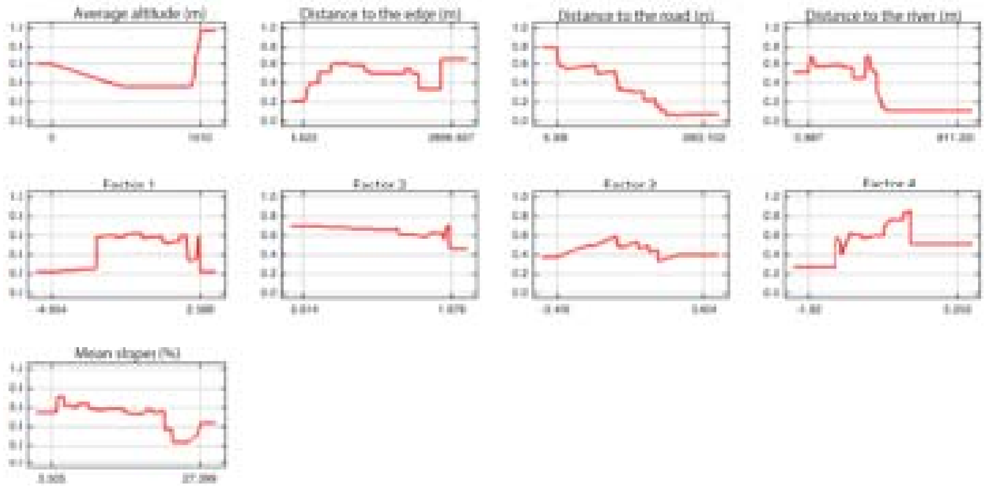

Figure 6. Response curves of environmental variables to Maxent model.

Figure 6 shows to what extent each environmental variable affects Maxent prediction. Abscissa axis corresponds to the probability of presence of chimpanzee while ordinate axis corresponds to the range of each value. We can identify favoring, unfavoring or variable effect environmental factors influencing chimpanzee repartition.

- Favoring factors:

There are high probabilities of observing chimpanzees at high elevation (up to 1510 m), as well as when mature forest and regeneration forest (F1+) or degraded and regeneration forest are associated (F2+).

- Unfavoring factors:

The more distance to the road or to the rivers increase, the less we have chances to meet chimpanzees. It is the same when slopes are between 23 to 28%, and when herbaceous and degraded forest are combined in the same area (F1-).

- Variable effect factors:

Depending on local factors, distance to the edge can favor chimpanzee presence. The habitat factors 3 (humid areas) and 4 (herbaceous and mature forest) apparently influenced the presence probability beyond some thresholds.

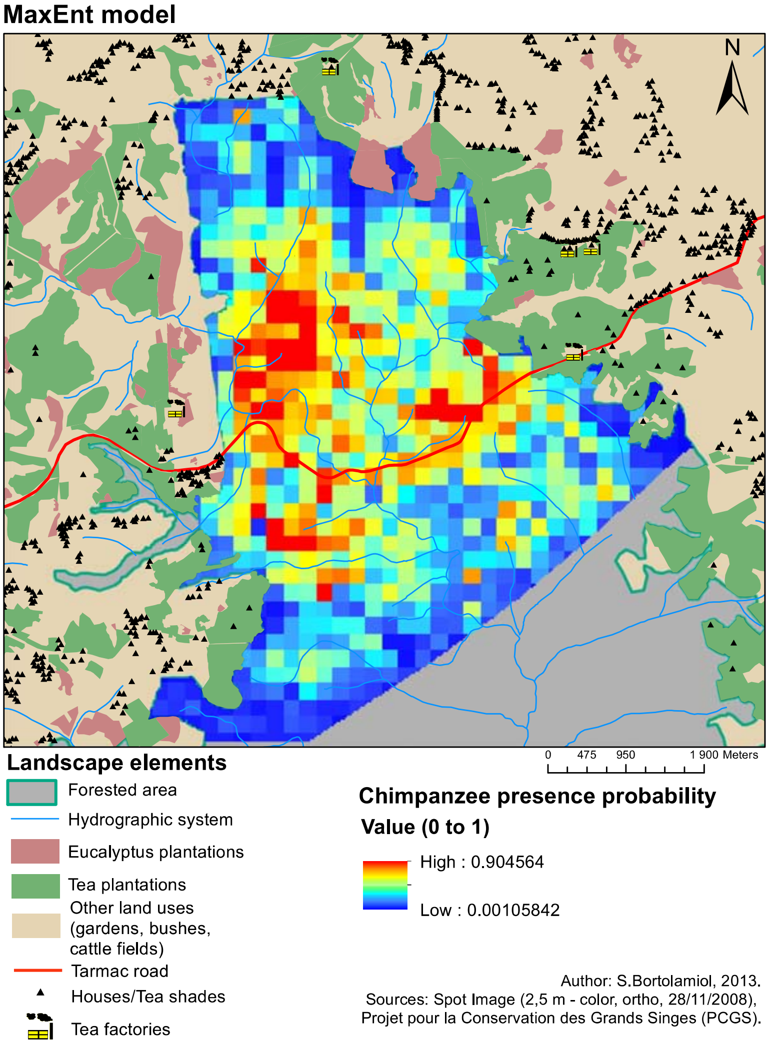

Figure 7. Maxent model

Chimpanzees have high probabilities of being encountered more frequently when they are near the road or forest edges (*Figure 7*). The cohesion of both models –Kernel and Maxent- is verified by a linear correlation (R^2= 0,377; $p < 0,0001$).

3.3.3 Deducing Interactions Between Wild Animals and Human Population from a Buffer Analysis

In the 2500m buffer zone around the chimpanzees home range, the most represented land-use is those which gather gardens, with crops, wetlands and bush (72 %), followed by tea (24%) and eucalyptus (4%) plantations. 1505 houses and 4 tea factories have been counted.

Frequency and damages of crop-raid by wild animals can vary in a season in function of crops planted and distance to the forest edge.

From interviews conducted with local communities, chimpanzees are not the most seen and damageable wild animal in people's gardens. In every interview (N=28), elephants have been cited as the most destroying mammal. Chimpanzees are more rare (N=20) and less damageable than elephants, but they are targeting crops in particular: maize, guava and sugarcane. We used UWA record book to estimate which villages were seeking more support from UWA rangers.

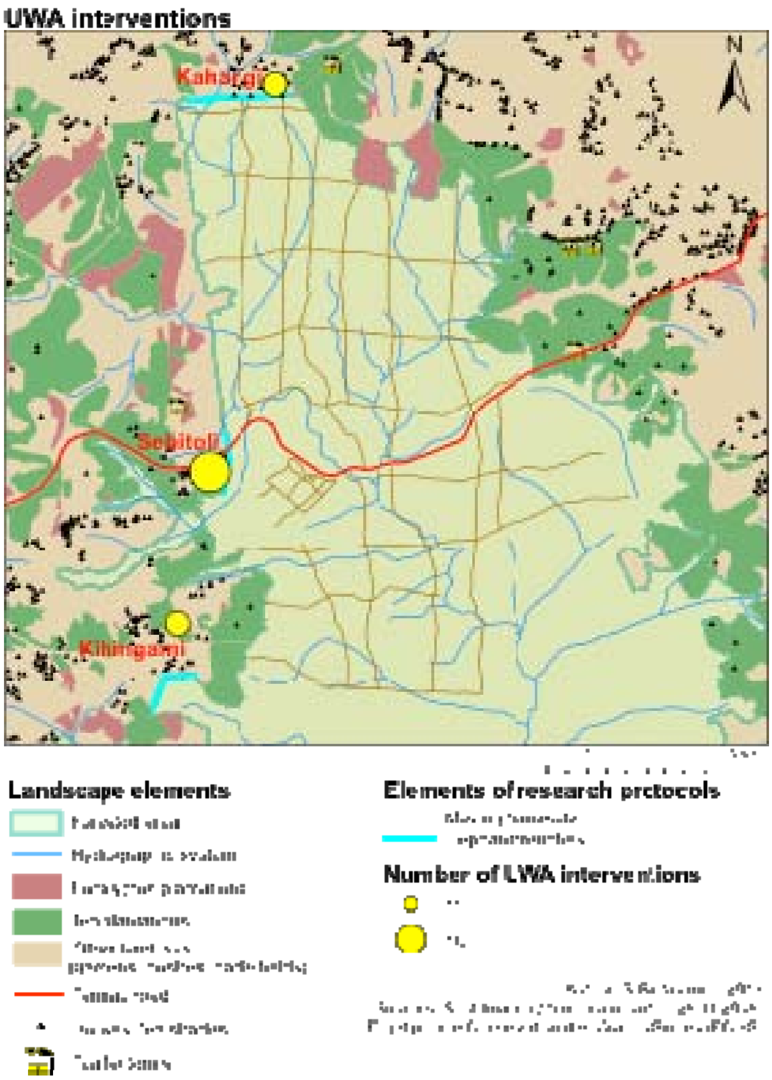

Figure 8. Number of UWA interventions per village in 2012.

In 2012, UWA rangers took action 67 times, in 40 out of 67 they chased away wild animals in the 3 villages where we conducted interviews (N=57 for elephants, N= 6 for baboons, N= 1 for chimpanzee, N= 1 for buffaloes, N= 2 times for unknown carnivore animals).

If we consider that the number of intervention is correlated to the number of wildlife incursion into people's gardens, Sebitoli, the closest to the forest edge, seems to be the village that is mostly suffering from wildlife damages.

It seems that local communities are soliciting UWA interventions more frequently for elephants than for chimpanzees.

4. Conclusion

Combining scales, data from different disciplines and spatial analysis allow us to better understand local factors that influence Sebitoli chimpanzee community and its high density (4.4 individuals/km²).

While their home range covers most of the protected forest, chimpanzees are concentrated in nucleus where forest-cover is heterogeneous, with a diversity of food resources. The proximity of tarmac road and of river are favoring factors, according to the results of the Maxent model, as well as high elevation areas. Chimpanzees do not avoid forest edges, particularly those connected to high proportion of gardens and plantations, where they may find extra food resources and of surrogate habitats.

Many authors have shown that chimpanzees require optimal environmental conditions (Turner et al. 2003, Kerr & Ostrovsky 2003), which is not the case of the Sebitoli study area. Nevertheless, other authors insist on the importance of food resource abundance (Potts 2009, Hockings et al. 2009), which is confirmed by our study.

The high density of chimpanzees means that they require a high quantity of food, the main part inside the forest and a complement outside it. Our study have confirmed the importance of distance and spatial patterns for the understanding of the interactions between chimpanzees, landscape and human population. It also gives some keys for a better management of conservation of nature in an anthropogenic environment.

References

Alexandre F, Génin A (2008) Continu et discontinu dans l'espace géographique. PUF, Tours, pp. 444.

Debinski DM, Ray C, Saveraid EH (2001) Species diversity and the scale of the landscape mosaic: do scales of movement and patch size affect diversity? Biol.Cons. 98: 179-190.

Boyle SA, Lourenço WC, Da Silva LR, Smith AT (2009) Home Range Estimates Vary with Sample Size and Methods. Folia Primatol. 80: 33–42.

Caldecott J, Miles J (2009) Atlas mondial des grands singes et de leur conservation. UNESCO, Paris. pp. 1-492.

Campbell-Smith G, Campbell-Smith M, Singleton I, Linkie M (2011) Apes in Space: Saving an Imperilled Orangutan Population in Sumatra. PLoS ONE 6 (2): e17210.

Chapman CA, Wrangham R (1993) Range use of the Forest Chimpanzees of Kibale: Implications for the understanding of Chimpanzee social organization. Am.J.Primatol. 31 (4): 263-273.

Chapman CA, Chapman, LJ (1997) Forest regeneration in logged and unlogged forest of Kibale National Park, Uganda. Biotropica, 29 (4): 396-412.

Chapman, CA, Lambert JE (2000) Habitat alteration and the conservation of African primates: case study of Kibale National Park, Uganda. Am. J.Primatol., 50: 169–185.

Dickson BG, Jenness JS, Beier P (2005) Influence of vegetation, topography, and roads on cougar movement in southern California. J.Wild.Manage. 69: 264-276.

Di Salvo M, Gadais M, Roche-Woillez G (2005) L'estimation de la densité par la méthode du noyau – méthode et outils. Notice analytique commanditée par le Ministère de l'équipement. pp. 26.

Elith J, Phillips SJ, Hastie T, Dudik M, Enchee Y, Yates CJ (2011) A statistical explanation of Maxent for ecologists. Divers.Distrib.17: 43-57.

Fielding A, Bell H, JF (1997) A review of methods for the assessment of prediction errors in conservation presence/absence models. Environ. Conserv. 24: 38–49.

Fortin MJ, Dale MRT, Hoel J (2006) Spatial Analysis in ecology. Encyclop. Environmetrics, pp. 1-380.

Fotheringham AS, Brunsdon C, Charlton M (2000) Qualitative geography - Perspectives on Spatial Data Analysis. Sage, London. pp. 1-270.

Goodall J (1986) The chimpanzees of Gombe: patterns of behaviour. Cambridge: Belknap Press. pp. 1-673.

Grueter C, Li D, Ren B, Wei F (2009) Choice of analytical method can have dramatic effects on primate home range estimates. Primates, 50 (1): 81-84.

Hartter J, Goldman A, Southworth J (2011) Responses by households to resource scarcity and human-wildlife conflict: Issues of fortress conservation and the surrounding agricultural landscape. J. Nature Conserv. 19 (2): 79–86.

Hartter J (2010) Resource use and ecosystem services in a forest landscape. Soc.natural res. 23, 207-223.

Hockings KJ, Anderson JR, Matsuzawa T (2009) Use of Wild and Cultivated Foods by Chimpanzees at Bossou, Republic of Guinea: Feeding Dynamics in a Human-Influenced Environment. Amer. J.of Primatol., 71: 636-646.

International Union for Conservation of Nature (IUCN). http://www.iucnredlist.org/, consulted 04/14/2013.

Johns BG (1996) Responses of chimpanzees to habituation and tourism in the Kibale forest, Uganda.Biol. Conserve. 78, 257-262.

Junker J, Blake S, Boesch C, Campbell G, Du Toit L, , Duvall C, Ekobo A, Etoga G, Galat-Luong A, Gamys J, Ganas-Swaray J, Gatti S, Ghiurghi A, Granier N, Hart J, Head J, Herbinger I, Cleveland Hicks T, Huijbregts B, Imong IS, Kuempel N, Lahm S, Lindsell J, Maisels F, McLennan M, Martinez L, Morgan B, Morgan D, Mulindahabi F, Mundry R, N'Goran KP, Normand E, Ntongho A, Tiku Okon D, Petre CA, Plumptre A, Rainey H, Regnaut S, Sanz C, Stokes E, Tondossama A, Tranquilli S, Sunderland-Groves J, Walsh P, Warren Y, Williamson EA, Kuehl HS (2012) Recent decline in suitable environmental conditions for African great apes. Div.Distrib. 1-15.

Kerr JT, Ostrovsky M (2003) From space to species: ecological applications for remote sensing. Trends Ecol.Evol., 18 (6): 299-305.

MacKenzie CA, Chapman CA, Sengupta R (2011) Spatial patterns of illegal resource extraction in Kibale National Park,Uganda. Environ. Conserv.39 (1): 38-50.

Mohr CO (1947) Table of equivalent populations of North American mammals. Amer.Midland Natur. 37, 223-247.

Newton-Fisher NE (2003) The home range of the Sonso community of

chimpanzees from the Budongo Forest, Uganda. Afric.J.Ecol.41: 150-156.

Naughton-Treves L, Chapman CA, Wrangham R (1998) Temporal patterns of crop-raiding by primates: linking food availability in croplands and adjacent forest. J.app.Ecol. 35: 596-606.

Phillips SJ, Anderson RP, Schapire RE (2006) Maximum entropy modeling of species geographic distributions. Ecol. Model., 190 (3-4): 231-259.

Potts KB, Chapman CA, Lwanga JS (2009) Floristic heterogeneity between forested sites in Kibale National Park, Uganda: insights into the fine-scale determinants of density in a large-bodied frugivorous primate. J. Animal Ecol. 78 (6): 1269–1277.

Steiniger S, Timmins TL, Hunter AJS (2010) Implementation and comparison of home range estimators for grizzly bears in Alberta, Canada, based on gps data. Poster, GIScience 2010, 6ème Conf.Int. Sc. Inf.Géogr.,Zurich, Suisse.

Struhsaker TT (1997) Ecology of an African rain forest: logging in Kibale and the conflict between conservation and exploitation. Gainesville: Univ.Florida Press. pp. 1-432.

Turner W, Sterling EJ, Janetos AC (2001) Introduction. Conserv.Biol.15 (4): 832-834.

Uganda Wildlife Authority (2005) Ground census of mammals in Kibale national park. Rapport scientifique: UWA Monitoring and research Unit – Kibale. pp. 19.

Wrangham R (1996) Ecology and social relationships in two species of chimpanzee. Ecological Aspects of Social Evolution. D. I. Rubenstein and R. Wrangham. Princeton, New Jersey, Princeton University Press: 352-378.

Acknowledgments

Data have been collected thanks to a partnership signed between Museum national of natural history (MNHN – Paris), Uganda Wildlife Authority and Makerere University. Field trips have been granted by Museum national of natural history/ATM 16, ANR JC-JC SAFAPE, We are particularly grateful to the field assistants and the farmers to help us in our research.